GAS CHROMATOGRAPHIC METHOD FOR OBTAINING DISTILLATION CURVES FOR PETROLEUM PRODUCT FRACTIONS AUTOMATICALLY

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(NASA-TT-F-16245) GAS CHROMATOGRAPHIC METHOD FOR OBTAINING DISTILLATION CURVES FOR PETROLEUM PRODUCT FRACTIONS AUTOMATICALLY (Scientific Translation Service) 20 p HC $3.25 CSCL 07D G3/25

N75-20499

Unclas 14723

Translation of : "Metodo Gascromatografico per l'ottenimento Automatico di Curve di Distillazione Relative a Frazioni di Prodotti Petroliferi." Revista Di Combustibili, Vol. 14, 1970, pp. 536 - 542.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 APRIL 1975

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STANDARD TITLE PAGE

1. Report No. NASA TT F-16,245	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle GAS CHROMATOGRAPHIC METHOD FOR OBTAINING DISTILLATION CURVES FOR PETROLEUM PRODUCT FRACTIONS AUTOMATICALLY		5. Report Date APRIL 1975 6. Performing Organization Code
7. Author(s) L. E. Green		8. Performing Organization Report No. 10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw-2483 13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of " Metodo Gascromatografico per l'ottenimento Automatico di Curve di Distillazione Relative a Frazioni di Prodotti Petroliferi" Revista Di Combustibili, Vol. 14, 1970, pp. 536 - 542.

16. Abstract

A description is given of a method making it possible to analyze any petroleum product fraction which falls within the range of the new ASTM method with one single gas chromatograph. This method makes possible a standard determination of the standard distillation curve with a gas chromatograph.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	20	

GAS CHROMATOGRAPHIC METHOD FOR OBTAINING DISTILLATION CURVES FOR PETROLEUM PRODUCT FRACTIONS AUTOMATICALLY

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Introduction

The main separation procedure used in the petroleum and /536* the petrochemical industry is distillation. The products are mainly complex mixtures of hydrocarbons which are marketed with certain specifications pertaining to the distillation curve. Many distillation processes have been traditionally used in the laboratory to determine this curve. The most widely used methods are the ASTM D-86 [1] and the equivalent at reduced pressure ASTM D-1160 [2]. These methods consist of rapid single plate distillations, which may reach a satisfactory accuracy, but the data obtained are poorly related to the effective distribution of the boiling points of the sample. Many efforts have been made to correlate the ASTM distillation curve and the distillation data for the various boiling points, but all these correlations suffer from the limitations inherent in the ASTM methods.

For a more accurate characterization of the sample one uses a long laboratory distillation, commonly called "true boiling point" (TBP). There is still no standard procedure for a distillation of the TBP type, and columns with considerably different efficiencies (from 20 to 100 theoretical plates) have been used. The technicians used the TBP distillation data for studying processes, analyzing raw materials and for studies on the performance of pilot plants: this data would also be extremely useful for controlling production processes. Still,

*Translator's Note: Numbers in margin indicate pagination of original foreign text.

the time required for a TBP distillation - from 6 to 100 hours of continuous operation - makes it impossible to use it to control production units, and the necessary expenses limit the practical usefulness drastically to studying processes.

Neither the very long TBP distillations nor the ASTM methods succeed in establishing the initial and final boiling points, and practically the only point where the data obtained with the two methods agree is located approximately at the mid-point. The necessity for finding a faster and more reliable distillation method was emphasized by Braun, Thompson and Fenske [4]: they maintain that, according to many engineers, one cannot make advances in measurements in the technology of gasoline as long as the main inspection methods are ASTM distillation and API gravity.

Gas chromatographic methods have been developed in order to obtain distribution data on boiling points, and several authors [3, 5, 6, 7, 8, 9, 10, 11] have specified the instrumentation and the procedures used. The gas chromatographic procedures have probably suffered from the lack of standardization and have found very limited acceptance. Nevertheless, the establishment of a study group for GC distillation in the D-2 committee of the ASTM, section L, RDIV in the fall of 1967, has revived the interest in this technique. A method proposed for "determining the shape of the distillation curves for petroleum product fractions by means of gas chromatographic analysis" will appear as a preliminary method in one of the ASTM 1970 volumes.

This method is used only for samples with a final boiling point of 540°C or less, but the study group is working to extend the validity of the method to all fractions except those which start to boil above 540°C.

Method of operation

A sample is injected in a gas chromatographic column which is capable of separating the hydrocarbons in succession, depending upon their boiling temperatures.

The temperature of the column is programmed in accordance with a reproducible cycle and the area contained in the chromatogram is recorded for the whole range.

A calibration curve, obtained for the same conditions by injecting a known mixture of n-paraffins with boiling points which cover the interval expected for the sample, makes it possible to go up again from retention times recorded in the analysis to the boiling points. At fixed time intervals, and thus at known intervals of boiling point temperature, one thus /537
obtains the percentages of the vaporized mixture; they are obtained by integrating the area of the chromatogram.

From this data, one obtains the distribution of the boiling point temperatures, or the distillation curve. The main advantages of the gas chromatographic system most suitable for this analysis are indicated in Table I.

Complete automation of the ASTM method

A procedure has been developed which makes it possible to analyze any petroleum product fraction which falls within the range of the new ASTM method with one single gas chromatograph. The new Hewlett-Packard 7600A gas chromatograph system is used for analysis. It involves a completely automatic analytical system, which measures and injects samples, carries out periodic analyses under preset gas chromatographic conditions and supplies both in analog as well as in numeric form the retention times and the peak areas, which may subsequently be processed through a time sharing system terminal. Figure 1 shows a block diagram of the system and its components.

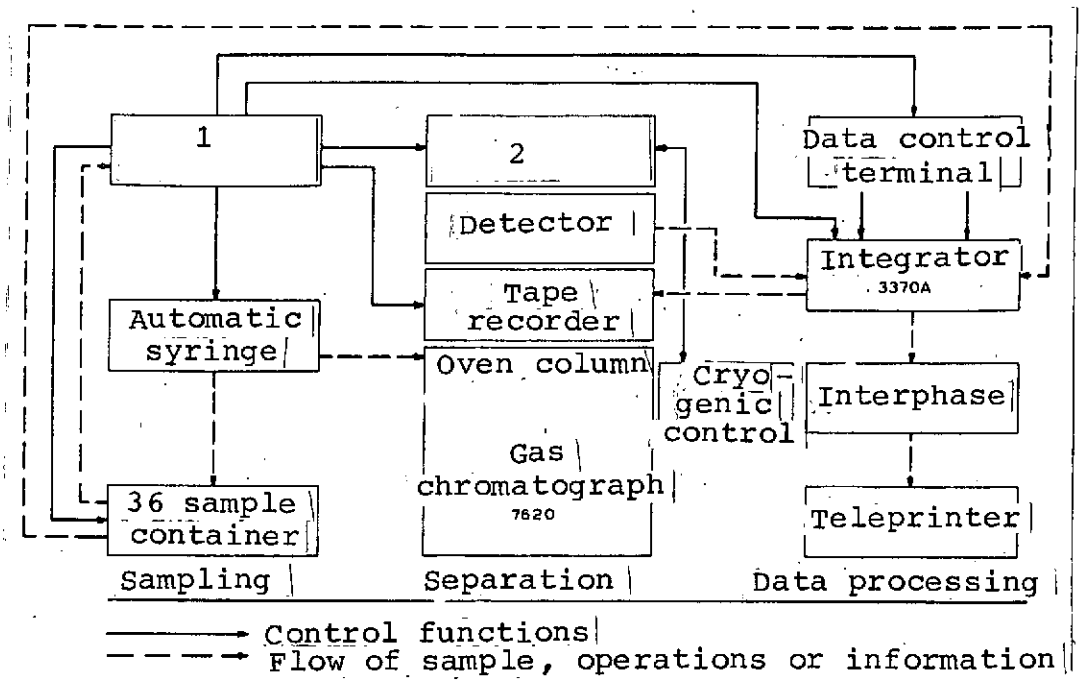

FIGURE 1.

1 - Control module for the automatic sampler

2 - Oven temperature control program

TABLE I

ADVANTAGES OF THE AUTOMATIC GAS CHROMATOGRAPHY SYSTEM

1. Non-polar columns of limited efficiency.
2. Automatic recycling of the programming of the temperature and the cooling off operations for temperatures from below the ambient temperature up to 400°C.
3. Rigorous observation of the time periods for heating up and cooling down the column and injecting the sample.
4. Absolute retention time accurately reproducible.
5. Thermal conductivity and flame ionization detectors.
6. The absence of cold points between the columns and the injection block or the detector.
7. Continuous integration of the area below the chromatogram with printing at quite accurate time intervals.
8. Stable base lines for a wide range of operations at programmed temperatures.
9. The data are processed by a computer.

The samples are placed in 1 ml vials, which are sealed with /538 an aluminum stopper containing a rubber septum lined with teflon. The vials are then loaded in the sample tray of the automatic sampler. Loading 36 samples requires a total time of approximately 10 minutes. The control module for the automatic sampler controls a standard microsyringe, which draws the sample from the vial and injects a calibrated volume of it in the gas chromatograph. The module also regulates the operation of the gas chromatograph and the data output. A potentiometer recorder provides a permanent analog type recording on paper, while at

TABLE II

ARRANGEMENT OF THE CONTROLS FOR THE 7600A SYSTEM AND GAS CHROMATOGRAPHIC CONDITIONS

Gas chromatographic conditions

Column: 122 x 0.6 cm; 3% OV-1 on 60/80 Diatoport S
Carrier gas: Helium; 40 ml/min
Column temperature: initial -20°C
final 380°C
Temperature program: 10°C/min
Injector temperature: 380°C
Detector temperature; 380°C
Hydrogen: 30 ml/min
Air: 600 ml/min
Electrometer: range 10^4
Sample size: 0.4 µl (0.18 µl calibration mixture)

Automatic sampler

Operation: automatic
Washing of syringe: max
Depression of the syringe: Stop 2 (stop 1 for calibration)
End of integration time: 40 min
Time for the analysis cycle: 62 min

Data control terminal

Manual input data: 01
Integration method: numerical (normal for calibration)
Integration delay: 0
Interval: 0.20 min

---

pre-set time intervals, the area of the chromatogram is punched on a tape and simultaneously printed by a teleprinter ASR-33, which is the integrator's normal printer. The 7600A system includes complete collections of programs (software), which make it possible to calculate the distillation curves and prepare analysis bulletins by using a time-sharing terminal. The system can be connected directly to a computer with an interphase card.

Table II shows the arrangement of all the controls and the operating conditions of the gas chromatograph. Once the columns have been prepared and the system is operating, the only thing which remains to be done to prepare the system for automatic analysis of as many as 36 samples is the following four steps:

1. Program the oven to the maximum temperature to be used. This guarantees a perfect initial temperature equilibrium for the first analysis.
2. Activate the cryogenic control and wait until the system automatically reaches the pre-set initial temperature.
3. While the column is heated and then cooled down to the initial temperature, load the samples into the sample container; when filling the vial, record the identity of the sample, the source (person who has taken the sample), the position in the container, and all other information necessary for calculation and preparation of the report, as shown by the examples of the printed form in Figure 2.
4. When the column has been cooled down to the initial temperature, push the starter button on the control module of the automatic sampler.

From this instant the system proceeds on its own to analyze all the samples, even more than once, if desired.

DATE OF ANALYSIS 4/23/69
DATE OF CALIBRATION 4/23/69
NUMBER OF SAMPLES 4

SAMPLE	IDENTITY	SOURCE	TRAY	METHOD	WEIGHTS		
					TARE	+ SAMPLE	+ I.S.
1	NAPHTHA #1	J PETERS	2	2			
2	REFORMATE	L GREEN	3	2			
3	L.V. DISTILLATE	L GREEN	4	2			
4	COKER RECYCLE	L MIKKELSEN	5	1	5.0168	6.0039	6.1628

NUMBER OF INJECTIONS PER SAMPLE 2
SAMPLER TRAY OF FIRST SAMPLE 2

*Use 1 for Internal Standard Method 2 for Normal Method
**Weights required only if Method 1 specified

Figure 2.

Calibration

For calibration one uses a mixture of n-paraffins whose boiling points are known and which cover the interval expected for the samples to be analyzed, and one proceeds as for the samples. During the calibration cycle the teleprinter prints the retention time for each peak. What is of interest is really the retention time, but the peak areas may serve to identify each peak. Since in the range where the method is valid one does not always have available pure hydrocarbons along the whole boiling point interval, the retention times of the peaks due to components which boil at a known temperature are introduced manually in the calibration program. It is a good rule to carry out the same calibration cycle each day to control the stability of the operating conditions and to make sure that the system operates correctly. If the retention times agree with the calibration stored in the memory of the computer, it is not necessary to make any changes.

Programs

The programs supplied with the system are written in Basic so that no programming experience is necessary to process the data resulting from a series of analyses. At each stage the computer requests the information necessary, and the operator only needs to type the number or the word requested on the terminal and wait for the next instruction. A part of the computer-operator dialog for obtaining a calibration is shown in Figure 3. The phrases which preceed the question marks are written by the computer; the operator limits himself to writing numbers or the monosyllables of the response. There are devices for correcting possible errors in reading in the data, and an internal diagnostic system advises the operator if he does not respect the correct order in typing the boiling point temperature or the retention times.

After the calibration program has been run for the first time, it is only necessary to introduce the new retention times for subsequent updating of the program, provided, of course, that the same mixture is used for the calibration. If the /539
operator had responded to the first question with a "2" rather than with a "1", the computer would have skipped all the other questions and would only have requested that the retention times be fed in. If the integrator time was decided in seconds, the computer would have requested the retention times in seconds rather than in minutes, as in the case in Figure 3.

At the end of the calibration procedure the operator may choose to have a summary of the results of the calibration, as in the case in Figure 4. The accuracy of the approximation of the curve calculated by the computer can be controlled by comparing the actual boiling points ("y-actual") with the calculated boiling points ("y-calc") for each component.

```
GET-BPCAL
100 FILES NEWSD
RUN
BPCAL

TO PERFORM A COMPLETE CALIBRATION ENTER 1
TO UPDATE ONLY RETENTION TIMES ENTER A 2  ?1

ENTER DATE (20 CHARACTERS MAX)   ?10/17/69

ENTER SAME METHOD NAME USED IN LINE 100   ?NEWSD

ENTER NUMBER OF COMPOUNDS (6 MINIMUM
44 MAXIMUM) TO BE USED FOR CALIBRATION   ?20

ARE BOILING POINTS IN DEGREES C OR F   ?F

ENTER BOILING POINT TEMPERATURES OF CALIBRATION
COMPOUNDS IN ASCENDING ORDER

COMPOUND 1       ?-44
COMPOUND 2       ?31
COMPOUND 3       ?97
COMPOUND 4       ?156
COMPOUND 5       ?209
COMPOUND 6       ?258
COMPOUND 7       ?303
COMPOUND 8       ?345
COMPOUND 9       ?385
COMPOUND 10      ?421
COMPOUND 11      ?486
COMPOUND 12      ?519

DO YOU WANT TO RE-ENTER BOILING POINTS   ?NO

IS INTEGRATOR TIME IN MINUTES OR SECONDS   ?MIN

HOW MANY MIN BETWEEN 'PRINT AREA' COMMANDS   ?.20

ENTER RETENTION TIMES (IN MIN) OF CALIBRATION
COMPOUNDS AS DETERMINED FROM CALIBRATION RUN

PEAK 1           ?.87
PEAK 2           ?1.47
PEAK 3           ?2.86
PEAK 4           ?4.67
PEAK 5           ?6.55
PEAK 6           ?8.42
PEAK 7           ?10.19
PEAK 8           ?11.85
PEAK 9           ?13.37
PEAK 10          ?14.88
PEAK 11          ?17.47
PEAK 12          ?18.76
PEAK 13          ?19.98
PEAK 14          ?20.97
PEAK 15          ?21.81
PEAK 16          ?23.74
PEAK 17          ?27.14
PEAK 18          ?30.06
PEAK 19          ?32.66
PEAK 20          ?34.95

DO YOU WANT TO RE-ENTER TIMES   ?NO
```

Figure 3.

```
DO YOU WANT A SUMMARY OF THE CALIBRATION RESULTS   ?YES

          METHOD 'NEWSD' AS CALIBRATED ON 10/17/69

THE FOLLOWING POLYNOMIAL WAS FIT TO THE DATA:

  Y=C1+(C2)(Z)+(C3)(Z↑3)+(C5)(Z↑4)+(C6)(Z↑5)

     WHERE:   Z=LOG X
              X=RETENTION TIME IN MIN
              Y=TEMPERATURE IN DEGREES F
          C 1       =-20.7918
          C 2       =153.577
          C 3       =71.9776
          C 4       =40.1533
          C 5       =-8.89391
          C 6       = 1.64262

X-ACTUAL     Y-ACTUAL     Y-CALC       DIFF        PCT-DIFF

  .87          -44          -44          0            0
 1.47           31           30         -1           -3.23
 2.86           97           99          2            2.06
 4.67          156          156          0            0
 6.55          209          208         -1           -.48
 8.42          258          257         -1           -.39
10.19          303          303          0            0
11.85          345          345          0            0
13.37          385          384         -1           -.26
14.88          421          423          2            .48
17.47          488          489          1            .2
18.76          519          521          2            .39
19.9           546          550          2            .36
20.97          576          578          2            .35
21.81          600          599         -1           -.17
23.74          651          648         -3           -.46
27.14          736          734         -2           -.27
30.06          809          808         -1           -.12
32.66          874          873         -1           -.11
34.95          938          931          3            .32

GOODNESS OF FIT = .9999 66

CALIBRATION IS COMPLETE.  DATA IS STORED IN FILE 'NEWSD'.
```

Figure 4.

The system for calculating a whole series of samples is very simple. In the form of a dialog, as always, the computer requests the information recorded on the sample analysis form (Figure 2). The complete computer-operator dialog takes place only once at the start of the calculation for the total number of samples analyzed in a series: this is shown in Figure 5. In the example one considers the case of a single sample; on the other hand, if there were more samples, the computer would request the identification of the sample and the type of method for each sample in the series.

After the dialog in figure 5, the system does not require further attention from the operator; it reads the perforated tape for the first cycle, determines the initial and final boiling points, calculates the percentages volatilized, assigns the boiling point temperature to each point and prints the analysis report. The procedure is repeated automatically until all the tapes in the analysis have been processed. Figure 6 shows a final analysis report.

System performance

Since the boiling points are assigned on the basis of the calibration curves while correlating boiling points with retention times, the accuracy of the method depends very much on the ability of the system to obtain accurately repeatable rentention times for all the compounds. In order to test the repeatability of the absolute retention times during a prolonged period of unguarded operation, 19 consecutive cycles were carried out with vials containing the calibration mixture. The data obtained have been summarized in table III. The repeatability is excellent over the whole interval of boiling points. The most severe test of repeatability is obtained by considering the spread in the various data, i.e., the difference between the maximum and the minimum values; in this way one will immediately discover even one single bad value, which might not appear from the standard deviation. In the worst case the spread was 0.25 minutes for a peak with a retention time of 31 minutes. /540

TABLE III

REPEATABILITY OF THE ABSOLUTE RETENTION TIME, SYSTEM 7600A (-20 - 380° C AT 10°/min); N-PARAFFINS (19 CONSECUTIVE UNGUARDED CYCLES).

Number of carbon atoms	B.P. °F	Mean retention time, min	σ	%σ	Spread
3	—44	0,87	0,021	2,3	0,06
4	31	1,27	0,030	2,6	0,11
5	97	2,04	0,027	1,3	0,08
6	156	3,57	0,022	0,62	0,08
7	209	5,27	0,018	0,34	0,06
8	258	6,87	0,025	0,36	0,11
9	303	8,33	0,026	0,31	0,13
10	345	9,74	0,020	0,20	0,08
11	385	11,09	0,020	0,18	0,07
12	421	12,38	0,021	0,17	0,07
14	488	14,77	0,027	0,18	0,09
15	519	15,89	0,032	0,20	0,11
16	548	16,94	0,033	0,20	0,11
17	576	17,94	0,037	0,21	0,13
18	602	18,79	0,038	0,20	0,13
20	651	20,69	0,044	0,21	0,15
24	736	23,84	0,055	0,23	0,19
28	809	26,56	0,065	0,24	0,22
32	874	28,94	0,070	0,24	0,24
36	928	31,08	0,080	0,26	0,25

```
GET-SIMDIS

100 FILES NEWSD
RUN
SIMDIS

ENTER DATE (20 CHARACTERS MAX)   ?10/17/69

ENTER NAME OF PERSON OR LAB PERFORMING
ANALYSIS (20 CHARACTERS MAX)   ?LOU GREEN

ENTER TOTAL NUMBER OF BOTTLES TO BE RUN (36 MAX)   ?1

ENTER NUMBER OF RUNS PER BOTTLE   ?1

ENTER TRAY NUMBER OF FIRST BOTTLE TO BE RUN   ?24

ENTER SAMPLE IDENTIFICATION AND NAME OF PERSON
SUBMITTING SAMPLE (MAX 20 CHARACTERS EACH) AS REQUESTED

BOTTLE # 24
   SAMPLE I.D.  ?TC GASOLINE
   SUBMITTOR    ?L. E. GREEN

ENTER 1 FOR INTERNAL NORMALIZATION CALCULATION
ENTER 2 FOR INTERNAL STANDARD CALCULATION    ?1

PLEASE LOAD INTEGRATOR TAPE AND PLACE
TAPE READER SWITCH IN 'AUTO' POSITION

-----------------------------------------------------------

DATA FROM BOTTLE #24    RUN 1    OF 1

 70008.0
?
  8880.0
?
  8808.0
?
  8888.0
?
  8298.0
?
  8812.0
?
  8581.0
?
  2192.0
?
  3861.1
?
  1192.0
?
  8133.0
?
  8824.0
?
  1381.1
?
  5906.1
?
  4778.0
?
```

Figure 5.

```
-----------------------------------------------------------

BOILING POINT DISTRIBUTION BY ASTM D XXXX-70T

REPORT TO: L. E. GREEN

SAMPLE F.I.D.:--------TC GASOLINE      INTERNAL NORMALIZATION CALCULATION
BOTTLE # 0    RUN 1    OF 1            CALIBRATED ON:--------10/17/69
ANALYZED ON:----------10/17/69         ANALYZED BY:----------LOU GREEN

  % OFF      DEG F        % OFF      DEG F
  -----      -----        -----      -----

  IBP         36
    1         41           51         205
    2         44           52         206
    3         46           53         207
    4         48           54         208
    5         50           55         210
    6         55           56         211
    7         84           57         213
    8         87           58         214
    9         89           59         219
   10         90           60         227
   11         90           61         231
   12         91           62         234
   13         92           63         236
   14         92           64         237
   15         93           65         237
   16         93           66         238
   17         94           67         239
   18         94           68         240
   19         95           69         240
   20         96           70         242
   21         96           71         243
   22         97           72         245
   23        103           73         247
   24        125           74         251
   25        166           75         253
   26        187           76         256
   27        189           77         255
   28        110           78         258
   29        111           79         262
   30        118           80         270
   31        137           81         280
   32        142           82         284
   33        144           83         286
   34        146           84         290
   35        147           85         293
   36        149           86         295
   37        151           87         298
   38        154           88         304
   39        157           89         319
   40        161           90         324
   41        165           91         326
   42        169           92         329
   43        172           93         332
   44        175           94         355
   45        180           95         330
   46        185           96         341
   47        190           97         344
   48        196           98         352
   49        200           99         363
   50        204          FBP         371
```

Figure 6.

The repeatability of the analyses was controlled with three types of radically different samples: table IV shows an example of data obtained from analyses repeated on this sample. Each one of these was selected because it had a specific problem which could probably affect the accuracy. "Naphtha", because it has a boiling point range of only 75 °C, which is a little above the limit of 55 °C provided for by this ASTM method; diesel oil, because of a very slow increase in the boiling point at the beginning of the curve and a long tail at the end; gasoline, because of its very low initial boiling point temperature. The accuracy obtained for these three samples is much better than what could be obtained with traditional methods of distillation. The spread in the values for each sample shows that an analysis of the diesel oil sample would normally be rejected by accuracy calculations.

All the data reported in this article have been obtained with a gas chromatograph using a flame ionization detector; however, according to the ASTM method, it is also permissible to use thermal conductivity detectors. In the various tests carried out by various laboratories on the ASTM method no deviation has been found between the result obtained using thermal conductivity detectors and those obtained with flame detectors; in fact, the two groups of data were in complete agreement. Because of this fact the thermal conductivity detector is probably always preferable because of its long-term reliability.

The economy of the automatic system

Table V shows a comparison between the costs incurred per sample with the automatic system and the costs one would incur if the operation was carried out manually. These costs have been calculated for the United States, but may also be indicative for Italy.

TABLE IV

REPEATABILITY OF THE SIMULATED DISTILLATION

	"Naphtha" (6 cycles)			Diesel oil (5 cycles)			Gasoline (6 cycles)		
% dist.	mean	σ	spread	mean	σ	spread	mean	σ	spread
Initial boiling point	237	0,89	3	285	1,8	5	15	0	0
1	240	1.4	5	329	1,4	4	21	0,58	1
5	248	1,3	3	369	0,55	1	72	0	0
10	258	0.45	1	390	0,55	1	81	0,58	1
15	261	0,89	2	405	0,55	1	92	2,0	4
20	266	0,89	3	421	1,4	3	108	2,1	4
30	274	1,1	3	447	1,3	3	155	0,58	1
40	281	0,84	3	481	1,1	3	192	0,58	1
50	287	0,55	2	510	1,9	5	211	0,58	1
60	292	0,71	2	538	2,2	7	237	0,58	1
70	297	0,84	2	570	2,3	6	259	0,58	1
80	305	0,71	2	599	2,9	7	302	0,58	1
85	310	0,45	1	616	3,6	9	330	0,58	1
90	316	0,89	2	638	5,9	12	342	0,58	1
95	332	0,71	2	690	8,7	44	360	0	0
99	361	0,55	1	839	5,7	15	390	0,58	1
Final boiling point	372	0	0	847	3,8	8	406	0	0

Note. - The results are expressed in $^{\circ}F$. - All the cycles were carried out automatically during night operation.

TABLE V

COMPARISON OF COSTS PER SAMPLE USING THE 7600A SYSTEM OR USING A MANUAL PROCEDURE.

	Cost per sample, dollars	
	System 7600A	Manual
Terminal time	1.66	-
Fixed cost for connecting	1.66	-
Total cost of calculation	2.66	6.25
Labor	1.88	4.69
Total cost	4.54	10.94

The cost of labor has been estimated at $6.25 per hour, and it is assumed that the system is used at only 50% of its capacity (10 samples per day) for 20 days per month. The cost of a time sharing terminal has been estimated at $10 per hour. Since the terminal time required to process the data from 10 samples and a calibration is approximately 100 minutes or 10 minutes per sample the terminal cost per sample is $1.66. If one also considers that the fixed cost for having a terminal amounts to approximately $200 per month, one has to add $1 per sample and arrive at a total cost for the sample calculations of $2.66.

The maximum time an operator requires to start up the system, load the samples, carry out a calibration and calculate all the results is 3 hours per day. At a cost of $6.25 per hour, this means a cost of $1.88 per sample with a total of $4.54 per sample analyzed with the automatic system. The labor costs for 20 samples is practically the same as for 10 samples and one will thus obtain a further reduction of the cost if there are more samples available for each analysis.

What do these figures say in comparison with the cost of an analysis carried out manually? If we assume that at least the area of the peaks is measured automatically, an expert employee will require at least one hour to calculate the data for one sample and record the results. That is $6.25 per sample spent for the calculation of data. With one single gas chromatograph 12 man hours are necessary to analyse 10 samples and carry out a calibration: this amounts to $4.69 per sample for labor. The total cost reaches $10.94 per sample. The cost of using the gas chromatograph has not been taken into consideration since it is the same in both cases. The data in Table V show that one may realize a saving of $6.40 per sample by using the automatic system. Even greater savings can be realized if a greater number of samples is available for each analysis.

Conclusions

The new ASTM method makes a standard determination of the /542
standard distillation curve with a gas chromatograph possible for the first time. The new Hewlett-Packard 7600A system for automatic GC analysis has been used with success to make the procedure described in the ASTM method completely automatic and to supply data similar to that obtained with traditional distillation methods of the TBP type, with a considerable saving of time and money. The accuracy available with the system has been shown to be better than what is obtained with traditional distillation methods for all samples which boil below 540°C. As compared to the case of a gas chromatograph operated manually, one obtains a saving of more than $6 per analysis. Simple programs make it possible to make full use of the system with time sharing terminals or small computers, even for personnel without previous programming experience. Special abilities are not required at any point in the analysis: the system is also for this reason very suitable to the control of production units.

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Translated for National Aeronautics and Space Administration under contract No. NASw 2483, by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.